

# Dynamic Measurements and Dynamically-Functioning Objects- Time Is to Look at Reality

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**Abstract-** It is shown that many dynamic tests and measurement technologies base on a changing measurement equation and that internal and external disturbances may change the dynamic functional of the same object and that the reaction of measurement transducer (measurement channel) changes not only in dependence on type of loads. The reasons are given which cause methodical metering errors and make it difficult to build idealized smart sensing and intelligent systems

**Index terms:** ‘bad’ posed problems, dynamic measurements, non-linear and chaotic dynamic, metering dynamic errors

## I INTRODUCTION

It is obvious: industry is undergoing changes in response to global forces of economy. Certainly, industry plays a central role to global economy and is shaping new future for development of knowledge intensive processes and product will be a cornerstone for growth and prosperity. There are functionality, quality, and performance [1]. In order to overcome barriers to product and process innovation, economy needs to seamlessly and accurately share and take full advantages of the latest technologies, essential to their competitiveness and goal realization [2]. Global standards and regulations are critical to the efficient operation of the global system and international markets.

One of the most convincing examples is an established value-added contribution of approximately  $\$1.6 \cdot 10^9$  manufacturing directly accounts for approximately 12-14% of US Gross Domestic Product [2]. New policy initiatives seek to make realistic gains for U.S. manufacturers, while recognizing the budget realities of the federal government. Many believe that real vision for the manufacturing sector - to be sustainable and globally competitive - can be achieved by increasing the return on US public investment dollars by making manufacturing-related federal policies and programs more effective [3].

In fact, American manufacturers are responsible for over 70% of research and development investment in the US economy. Novelty of solutions follows from manufacturing sector, too: nearly 80% of all US patents are tied with the industry [4]. There is a relative index of priorities. One often wonders the main mission is to promote innovation and the competitiveness of manufacturing through measurement technologies, service, and critical contribution to standardization [2].

It is not an obvious fact that dynamic measurement technologies play now preventive role in creation of any economy. At a time of great technical and economic changes, dynamic measurement technologies (DMT) are in a position of multiple applications to the real world [5]. Also, the DMT play one of the key roles in contemporary stage of development of economic potential in the world: they determine large extent successes and failures, too.

Real results depend on level of intellectual resources in considered field of knowledge [6]. At least three whales are included in consideration: knowledge generation for newest decisions, communication of knowledge in global economy (why we are here), and methods which can combine and integrate knowledge for decision making for highly customized technologies for processes and product.

Creation and development of new technique and technologies requires development of insight towards fields of knowledge tied to the DMT and addresses to dynamically functioning objects as non-linear, hybrid, time-variations, or distributed dynamic systems. Non-linearity and chaos are ordinary natural phenomena and are very individualistic.

Obviously, it is important to understand how to organize and carry out the dynamic test and measurements in order to receive conceptually correct and accurate results corresponding to putting up with the problem. There is a correctly framed problem and optimal well-founded measurement equation as one of the ways to reach minimum certainty, identify actual non-linear behaviour of dynamic structure, or processes. Of cause, in most cases one aspires to create an idealized measurement system or measuring channel.

What is the difference among posed problems? Well in most of cases, one overlooks methodical component of metering dynamic errors- this creates full complex of problems. Often there is a small cause to pervasive misunderstanding of consequences.

However, correct approach requires ‘additional’ expenses for ‘additional’ investigations of methodical correctness of measuring technologies.

## I I. BACKGROUND AND FRAMEWORK

The objective in this section is to demonstrate a problem, which is always present in dynamic measurement technology of dynamically functioning objects. The basic setup is given in Fig. 1:

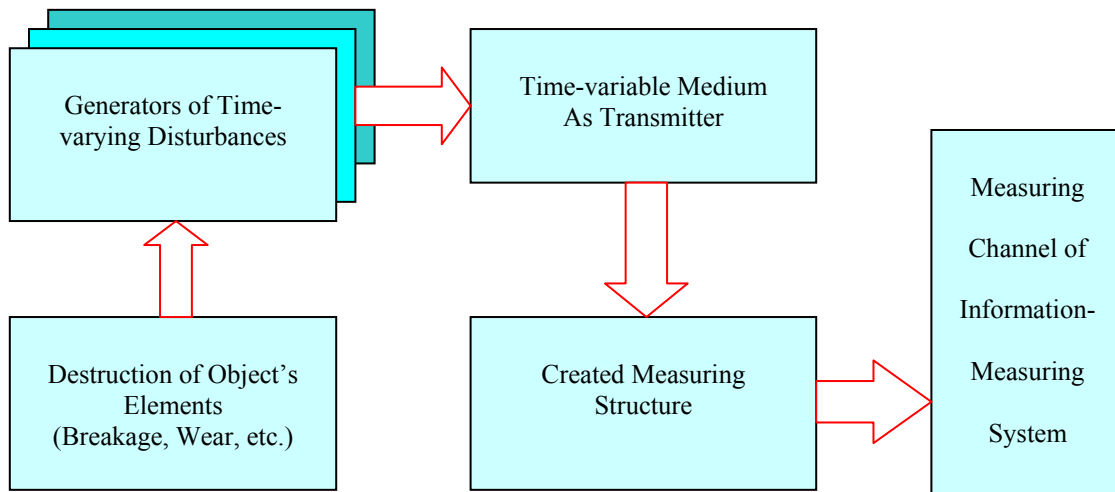


Fig.1. Structural scheme of considered problem

In reality, a process of destruction is identical physically with some variations. Indeed, generators may be different (destruction takes place at different zones of object and displays as different processes), or the same, so clearly, transmitting medium changes physical configuration

and physical properties, delivering different energy (with different distribution) as a function of a time, and penetrates the zones, where measuring transducers are placed. Consequently, there is different information on destruction, or on rapidly changing object conditions.

The DMT in a non-ordinary lacking ideal properties of medium of real Markov objects when measurement equation changes. This is a result of internal and external sources of non-linearity and interrelation between them. Main sources of non-linearity, on which the conventional paradigm between tests, measurements and analysis of objects are based, are presented in a number of fundamental research endeavors.

Non-linearity of objects has direct relation to structure of measuring channel and to ways to of information processing in intelligent systems.

Referenced in [7] examples are known. They consider:

- geometric non-linearity;
- inertia non-linearity;
- non-linear behaviour of materials from which the structure of object is designed and manufactured;
- damping-inflicted non-linearity;
- boundary conditions;
- damaged-structure non-linearity;
- small degradation of joints, and others.

In development of presentation, small degradation may introduce gaps between object elements inside of joints. What follows contains partial extraction of sources of non-linearity, which may happen in reality; however, such information is sufficient for analysis in this approach.

It is known that an inclusion of some mechanisms of non-linearity generates changes in common dynamics of object. Non-linearity gives rise to complex dynamic phenomena, including jumps, bifurcation, and chaos. Clearly, non-linearity is egoistically individual. Therefore, dynamics of the same manufactured objects is different.

Generated strong-impact non-linearity affects dynamics of object over broad range of stress rate, i.e., the common dynamics of object change again. Although it is often overlooked by specialists, non-linearity has a frequent occurrence with engineering objects and can drastically alter their behaviour. Any attempt to apply traditional linear analysis is certain to fail. There will be situations where non-linearity, if not accounted for, introduces a threat of a 'catastrophe' [7].

It is an obvious observation that different shifts directed to create an adsorption of information about processes in such conditions cannot give reliable results in spite of all efforts of creators of information processing technologies to illuminate the root of the problem of 'thinness' analyzing both redistributed and processed data.

### III. 'CLASSICAL' APPROACHES TO EXTRACTION OF INFORMATION ABOUT BEHAVIOUR OF AN OBJECT OF INVESTIGATION AND IT PROCESSING

As a rule, 'classical' dynamic measurement technologies consider sources of disturbances for comparatively 'stable' transmitting media, which do not distort the condition of measured processes in the framework of the concrete accuracy. It is considered in conditions, when transmitting media do not change information flows, or gives in by analytical correction.

An unfolded example of measurements relating to a measurement problem of such type is presented in Fig. 2 [8].

'Classical' measurements of object's reaction to random shock excitation are directed to foresee behaviour of object in other conditions of functioning.

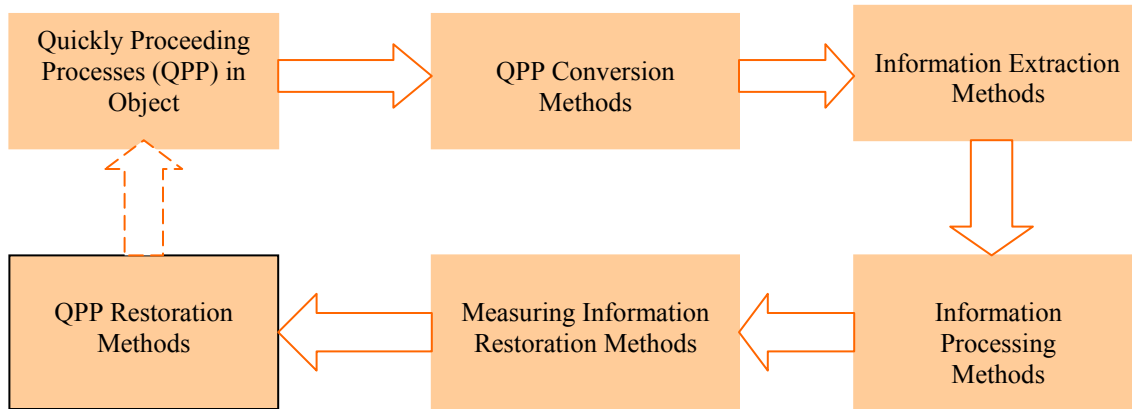


Fig.2. Block- scheme of information processing of a measuring problem

Such approach is known and is based on understanding of a model presented in Fig. 3 [9]. The referenced model was applied as one of the most powerful instruments, and helped to solve numerous problems.



Fig. 3. Typical testing approach

So called ‘random processes’ are oscillations of objects subjected to a shock temporally and perhaps spatially in randomly varying internal, external dynamic environments. Mathematical and experimental study is particularly important because practically all real physical systems are subjected to random dynamic environments at some time during their lives, and many systems fail due to the effects of these exposures. These studies of random processes have historically been pursued to explain observed phenomena, predict the characteristics of object responses to unrealized environments, aid in the design of mechanical objects and systems isolate them, and demonstrate the survivability and response character of physical systems. As information processing instrument, spectral density has been the *de facto* fundamental quantitative descriptor of stationary random processes in use today. Of course, a comprehensive theory of random excitation and measurements was needed not only to accurately predict structural response [9] but extract information about possible destruction. The only possible caveat is that considered approach carries integral appraisal.

#### IV. SOME PARTICULARITIES OF DYNAMIC BEHAVIOUR OF AN MEASURING CHANNEL IN MEDIUM OF RAPIDLY TIME-VARYING PROCESSES

In some cases, methodical peculiarities of dynamic measurement technologies of complicated processes or behaviour of distributed structures a component of general problem are partly based on 'behaviour' of measurement equation [10], and partly- on 'behaviour' of a measuring channel of a measuring system. Sometimes, a measurement equation does not change in frame of the setting error. However, the dynamic error of transformation of measuring channel may change during dynamic measuring procedures.

In reality, some measurement equation changes during of measurements, i.e., metering dynamic error is a function of the time. This may occur as a result of an interaction with measuring transducer of rapidly time-varying mechanical quantities (MTMQ) and by an impact of part of the object of measurements during dynamic measurements of dynamic processes, or as a result of changing dynamics of chaotically functioning structure, and its elements [11]. It is not obvious that a measurable structure with 'swimming' dynamic characteristics may be created. In real medium, the measuring disturbances differ from 'ideally' simulated loads. Indeed, new measuring structure appears, and it has *new metrological characteristics*, or functionals. Indeed, metrological characteristics of the MTMQ do not change and they are the same as a result of dynamic calibration. One of the examples is presented in Fig. 4:

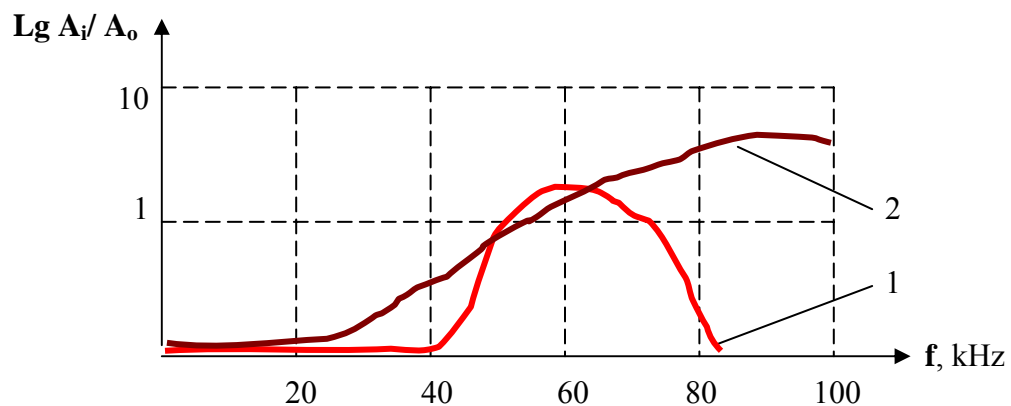


Fig. 4. The MTMQ's calibrated characteristic (curve 1) and formed measuring structure as 'real' characteristic of measuring channel (curve 2)

However, it always does not happen that the DMT 'predict' the behaviour of objects and their functioning with a necessary level of accuracy. The problem of dynamic measurements, when dynamic characteristic of the MTMQ in fixed environment changes in independence with as to the place of the MTMQ on object is difficult for perception: new measuring structure may be formed, but what structure. Due to location limitation and possible high stress rate, however, MTMQ's have to be located in the area where process is severe. Then, when an event occurs, a short-time metering dynamic error of measuring channel is higher than relative contribution of changes evoked by a transformation of the measurement equation. Consequently, this part of metering dynamic error exerts influence.

Nevertheless, the MTMQ cannot be always a MTMQ with concentrated parameters. In development of understanding of dynamic measurement particulars, it is expedient to consider a

component of metering dynamic error created by transformation of the ordinary MTMQ to the MTMQ with distributed parameters and components. Dynamic characteristics of the MTMQ changes when the MTMQ functions as the transducer with distributed parameters. Such event is considered in [12-14].

It is an obvious fact that the MTMQ receives not only measuring quantity information about occurring rapidly changing processes but also information about other effects, which are physically destabilizing factors: they accompany measuring processes. Altogether, measured quantity and secondary effects influence the MTMQ, which is a part of measuring channel, and 'uses' as an optimal basis in any monitoring, diagnostic, and control systems.

Measurable rapidly time-varying processes change full dynamic characteristics, or functional of the MTMQ, too. Symbiosis of different wave processes in physical system 'object- MTMQ' is reason for it.

In the same time, the MTMQ possesses other properties, such as high sensitivity, wide dynamic range, high correlation signal/noise, high reliability, and ability to operate under difficult conditions. Nevertheless, they have relation to new physical system.

One of the ways to divide information received from an object of measurements and information generated by secondary effects is based on the deep understanding of mathematical models of the MTMQ as the MTMQ with distributed components and parameters, when wave effects are taken into consideration. For example, the solution of the problem for piezoelectric transducers can be realized in the form of traveling or standing waves; the solution is given in [12].

Thus, full dynamic characteristic of the MTMQ received as a result of calibration can change in conditions, when the MTMQ becomes the MTMQ with distributed parameters and components. In Fig. 5, one of results of relation 'the measuring transducer of mechanical quantities- the process' is shown. The MTMQ is operating in the semi-resonance mode under aforementioned conditions.

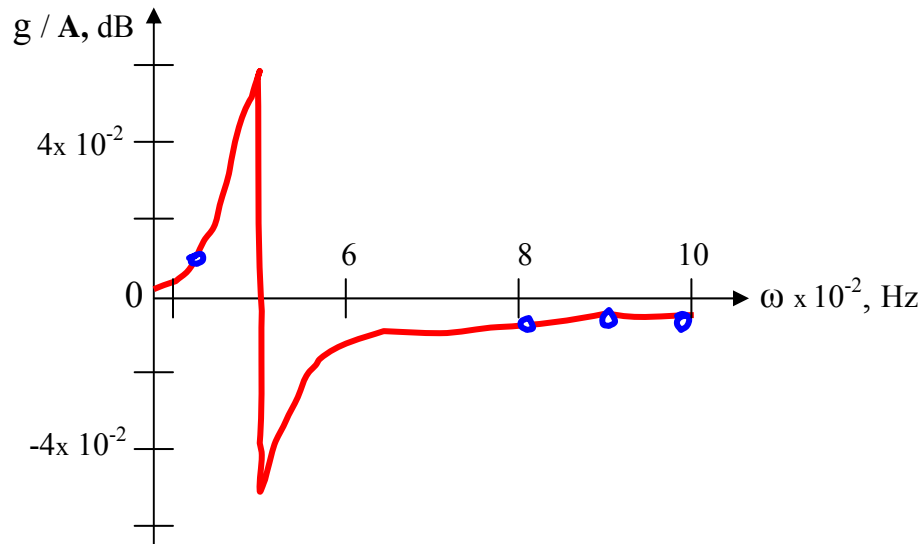


Fig. 5. Calculated amplitude-frequency characteristic of the MTMQ: the circles represent the experiment data [12]. The  $\mathbf{A}$  is a response of the MTMQ.

Several examples of relation between the MTMQ and the measurable process for concretized conditions of relation are presented in [15]. An analysis of processes proceeding inside of an object during loading shows that the same low-speed normal loading of the object can evoke the different reactions or responses of objects. It can happen. A response of a measuring channel during normal loading may appear as a response on the external high speed loading. Wave processes, formed as a result of relation between the MTMQ and an object, parameters of which are determined by the physics of processes in the zone of contact as internal processes in the MTMQ, may play the main role. Single-divisible wave process change the full dynamic characteristics of the MTMQ, however user do not know about it- the calibration do not see such changing.

The technique described in [16] is offered in order to extend the usable frequency range of the MT, to improve the accuracy of the measurements by a correction of time signal of a MT inverting of its calibrated frequency response, and to expand the use of existing transducers, as well as to increase the highest recommended usable frequency range, may not be used for considered applications... if calibration does not give some possibility to see considered phenomena. Unfortunately, it uses for dynamic measurements when the MT was calibrated in 'ideal' conditions; the dynamic metrological characteristics have to be received in conditions of such transducer's dynamic calibration, which gives in a frequency analysis and can response on marked 'anomalies'.

As an example, condition based preventive monitoring and diagnostics, failure preventive, and prognostics [17] as well as problems of control cannot be solved without extensive knowledge of measuring channel possibilities and limits. There is an identification of models, measurement equations, suitable measurements that should correlate with development faulty or abnormal object behaviour, extent of ability to diagnose the condition of the object, its components, or processes, and prediction of the remaining life of the equipment as well as provide advice-correcting solutions. The solution to such problems requires constant adjusting of measuring transducer and advanced measuring technology.

However, attempts to transfer solution of such problems to 'advanced' signal analysis techniques and technology only [18] have not been realized. It is well accepted: they may seem imperfect from the point of view of understanding of real problems.

## V. CONCLUSION

As a summary, there is considered symbiosis consisting time-varying generators, time-varying transmitting media, created metrological characteristics of measuring structure, which are a result of dynamics relation between a part of an object and a measuring transducer, and also a measuring transducer as an element of measurement channel with distributed parameters.

Presented analysis does not claim that it gives exhaustive answers (only provides examples which have a direct relation to practical application). However, it illustrates, that it is important to be scrupulous in analysis of components of measuring channel, structure dynamic measurement technologies, and information processing technologies.

These results can be used for applied and manufacturing metrology as well as for engineering applications to protect users from a number of inaccuracies, which could be by the basis for

practical decisions during a creation of smart sensing and intelligent systems and by a part of experimental analysis.

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